- Draft -

Determination of Start Emissions
as a Function of Mileage and Soak Time
for 1981-1993 Model Year Light-Duty Vehicles

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1.0 INTRODUCTION

MOBILE6 will allocate vehicle exhaust emissions to either those associated with engine start (start emissions) or those associated with travel (running emissions). This split allows the separate characterization of start and running emissions for correction factors such as fuel effects and ambient temperature It also allows a more precise weighting of these two aspects of exhaust emissions for particular situations such as morning commute, parking lots and freeways This document describes the methodology used to calculate start emissions as a function of mileage and soak time for use in MOBILE6. The results for model year 1981-1993 light-duty cars and light-duty trucks are presented. The deterioration of running emissions will be addressed in a separate document (Report Number M6.STE.004)

Section 2 describes the FTP data sources and the model year and technology groups which are used. Section 3 describes the methodology and models for determining start emissions. It is divided into three sub-sections The first sub-section describes the FTP cycle, the Hot505 cycle, and defines the basic unit of start emissions. The second sub-section describes the analysis of start emissions deterioration with mileage. The third sub-section describes the methodology used to predict start emissions as a function of soak time Section 4 illustrates how start emissions will be estimated in MOBILE6 as a function of both deterioration and soak time

2.0 DATA SOURCES USED

The datasets used to determine in-use deterioration are all based on FTP testing No IM240 data or data collected by a state I/M program were used. Three data sources were used: 1) the test results from the EPA laboratory in Ann Arbor, Michigan, 2) the data received from AAMA

-2-

(American Automobile Manufacturers Association) based on testing conducted in Michigan and Arizona, and 3) the API (American Petroleum Institute) data collected in Arizona. The model years in the dataset range from 1981 through 1993, and contain both cars and trucks Table 1 gives a breakdown by vehicle type, model year, and technology for the three datasets combined

In general, most of the 1990+ model year vehicle data were supplied by AAMA, and most of the pre-1990 data were supplied by the EPA laboratory testing. The API sample is a relatively small sample (99 cars and trucks) Its chief appeal is that the vehicles all have generally higher mileage readings that the rest of the sample (all over 100,000 miles) The other general trend in the data is toward PFI technology, and away from the others. This is seen in the 1990+ vehicles which are predominately PFI with some TBI still present The 1981 - 1989 model years start with a high percentage of carbureted and some open loop, but end with mostly TBI and PFI technology Although not explicitly shown in the tables, new catalyst technology was phased slowly into the fleet starting in the mid 1980's.

For analysis, the cars and trucks were placed into the model year/technology groups shown below

MY Group / Technology Type
1990-93 PFI
1990-93 TBI
1986-89 FI
1986-89 CL Carb
1983-85 FI
1983-85 CL Carb
1981-82 FI
1981-82 CL Carb
1981+ OPLP

The technology groups are closed-loop ported fuel injection (PFI), closed-loop throttle body injection (TBI), closed-loop carbureted (CARB), and open loop (OPLP). FI refers to a combination of PFI and TBI. These model year/technology grouping boundaries were selected in conjunction with the FACA In-Use Deterioration Workgroup on the basis of changes in emission standards or the development/refinement of new fuel metering or catalyst technologies It is assumed that as of 1990, carbureted technology had negligible market share, and will not be modeled. Because of the relatively large amount of 1990-93 fuel injected data, the category was split into PFI technology and TBI technology for both cars and trucks. This produces separate deterioration functions based on this fuel delivery technology and allows the modeling of the future penetration of PFI technology into the in-use fleet

3.0   DETERMINATION OF START EMISSIONS

3.1   Background

3.1.1   Overview of the Federal Test Procedure (FTP)

The Federal Test Procedure (FTP) is a test cycle which is used to certify new vehicles to emission performance standards (see 40 CFR Part 86, Subpart B, Section 86.144). The FTP consists of a cold start segment (Bag 1), a hot stabilized segment (Bag 2), and a hot start segment (Bag 3) Initially, the vehicle is stored for a minimum of 12 hours before testing to simulate a 12 hour overnight soak period. The vehicle is then driven over the cold start segment, which lasts 505 seconds over a length of 3 59 miles, and the emissions collected as Bag 1   Bag 2 emissions are then immediately collected from the hot stabilized segment, which lasts 867 seconds over a length of 3.91 miles   After a 10 minute soak, the 505 seconds of the start segment is then repeated and the emissions collected as Bag 3.

The FTP composite emission rate is a weighted combination of the three measured bags to represent two trips   The first trip is a cold start after a 12 hour soak, and the other is a hot start after a 10 minute soak   Each trip is a "LA4" cycle, which is a combination of the 505 cycle (either Bag 1 or Bag 3) and the Bag 2 cycle. In a typical FTP test, the Bag 2 is only measured once and the results are used for both trips   Since the 505 cycle is 3 59 miles long and the Bag 2 cycle is 3.91 miles long, each LA4 trip is 7.5 miles long. The cold start trip is weighted at 43% and the hot start trip weighted 57%   If the cold start trip is 43% of the driving, then the vehicle miles traveled (VMT) in Bag 1 (containing the cold start) is

FTP Bag 1 VMT Weighting = 43% * (3 59 miles / 7 5 miles) = 0 206

The hot start trip is 57% of driving, and the VMT weighting for Bag 3 (containing the hot start) is:

FTP Bag 3 VMT Weighting = 57% * (3 59 miles / 7.5 miles) = 0.273

The remaining VMT is from stabilized driving, represented by Bag 2. Since Bag 2 is used for both the cold start and hot start trips, it uses VMT weighting from both.

FTP Bag 2 VMT Weighting = (43% + 57%) * (3 91 miles / 7.5 miles) = 0.521

The standard VMT weighting of the bags reported in grams per mile for the full FTP are:

FTP = (Bag 1 * 0.206) + (Bag 2 * 0.521) + (Bag 3 * 0.273)

where the fractions represent the amount of vehicle miles traveled within the three modes during the FTP trip in grams per mile (g/mi).

3.1.2   Overview of the Hot Running 505 and Its Use

The FTP testing method outlined above does not allow the precise separation of start and running emissions, since Bags 1 and 3 contain both start and running emissions Bag 2 of the FTP does not contain an engine start; however, the driving cycle used in the second bag is significantly different from the cycle used for Bags 1 and 3   Thus, to estimate the amount of FTP emissions that can be allocated to engine start, the concept of the Hot Running 505 (HR505) is needed.

The HR505 is an extra 505 cycle performed immediately following bag 3 of the FTP It uses an identical driving cycle as the first and third bags of the FTP, but does not include an engine start For more information, refer to the document "The Determination of Hot Running Emissions from FTP Bag Emissions", report number M6 STE.002   With a HR505 emission result, it is possible to compare the results obtained from the HR505 to the results from Bags 1 and 3 of the FTP to determine the portions of Bags 1 and 3 attributable to start emissions following a 12 hour soak and start emissions following a 10 minute soak, respectively

Since the HR505 has not historically been included in FTP test programs, a method of estimating the HR505 was developed, as described in report M6 STE 002.   Briefly, HR505 emissions were measured from a sample of 77 vehicles tested under EPA contract The results from this vehicle sample were used to develop a correlation between the HR505 and FTP bag data This correlation was then used to estimate HR505 results for the FTP dataset used for this analysis.

3.1.3   Basic Start Emission Rate

For MOBILE6, the basic unit of engine start emissions is defined as a start after a 12 hour soak. The units for engine start emissions will be grams, instead of grams per mile, since start emissions will not be allocated by vehicle miles traveled. The engine start basic emission rate can be determined by subtracting the HR505 emission rate from the Bag 1 emission rate (in grams per mile) using the nominal distance traveled in the 505 driving cycle.

Basic Start Emission Rate (grams) = [Bag 1(g/mi) - HR505(g/mi)] * 3 59 miles

For illustration purposes, the average basic start emission rates (in grams) after a 12 hour soak were calculated for each model year and are shown in Tables 2a and 2b

Start emissions after a 10 minute soak can also be estimated from the Bag 3 and HR505 emission rates, analogous to the basic start emission rate:

Start Emissions after 10 minute soak (grams) = [Bag 3(g/mi) - HR505(g/mi)] * 3 59 miles

The average start emissions after a 10 minute soak are also shown in Table 2a and 2b for each model year

3.2   Basic Start Deterioration with Mileage

This section describes the methodology used to estimate start emission deterioration, and presents the basic deterioration rates versus mileage The basic start (i e , following a 12 hour soak) deterioration rates were obtained from simple linear regression of the Basic Start Emission Rate data (expressed as grams) versus mileage. The results are shown in Tables 3a, 3b, and 3c. Table 3a includes the deterioration rates for the fuel injected cars and Table 3b shows the rates for the fuel injected trucks. Table 3c shows the deterioration rates for the closed-loop carbureted and open-loop cars and trucks.

Separate deterioration rates were calculated for both cars and trucks, for each of the three pollutants, and for each model year/technology group. The exception is the 1981-82 fuel injected and closed-loop carbureted truck categories, which had zero data Because of the lack of 1981-82 FI and CL Carb truck data, the deterioration functions for the corresponding 1981-82 car categories were used. The effect of this substitution in the MOBILE6 model should be negligible due to the scarcity of older model year fuel injected trucks in the in-use fleet.

Selected results from Table 3a (cars only) are also shown graphically in Figures 1 through 3 for HC, CO, and NO_x for each model year/ technology group. For HC, the results are generally as expected with the new model years having lower start emission levels and deterioration rates than the older model years. However, comparing PFI and TBI for the 1990-93 cars shows TBI cars having slightly lower emission levels than PFI cars. This is somewhat of an anomaly since it is believed that PFI is a superior technology to TBI. However, both regressions were generally statistically significant at least at a 90% confidence level, and further analysis of the sample using scatter plots (not shown) revealed that the differences were not the result of outliers greatly influencing the sample Thus, the 1990-93 TBI vehicles will be projected to have slightly lower HC start emissions than the corresponding PFI vehicles.

Again for CO, the 1990-93 TBI category is slightly lower than the PFI category because of a lower ZML. Also, in this case, the 1986-89 model year group has slightly lower CO emissions than the 1990-93 PFI group.   However, in this case, the deterioration rate is not statistically significant for the TBI or 1986-89 model year groups Finally, the 1981-82 group is considerably higher than the other two groups with CO emissions at the 100,000 mile level almost twice as high as the other model year groups This is not unexpected since much of the 1981-82 fuel injection technology was in early stages of development.

For NOx, the emission levels and deterioration rates for all model year groups are generally the same The principal exception is the 1990-93 TBI group. For the 1990-93 TBI group, the deterioration rate is similar to the others, but the intercept is considerably higher.

3.3   Start Emissions Versus Soak Time

Start emissions will be a function of soak time so that MOBILE6 will be able to account for the entire distribution of soak times observed in the fleet This ranges from a minimum soak time of zero minutes up to a 12 hour soak period (720 minutes) Soak periods exceeding 12 hours will be assumed to be the same as for a 12 hour soak.

To develop the relationship between start emissions and soak time, the FTP database was used only to determine the engine start emissions after a 10 minute soak and a 12 hour (720 minute) soak (these are the only data points available). To predict start emissions for the entire range of soak duration, a model was developed from the two FTP points, and from testing done by California of the effect of soak time on engine start emissions (see CARB report "Methodology for Calculating and Redefining Cold and Hot Start Emissions")

The model which was developed uses the FTP start emission data from the two FTP soak times to adjust the curves presented in the California report The start emission data points at 10 minutes and 720 minutes are derived from the FTP dataset described earlier and are a function of pollutant, technology, model year group, and mileage. The California interpolation curves (California Soak Function) is a function of pollutant and catalyst type.

Mathematically, the start emissions of a given pollutant (in grams) as a function of soak time is shown as:

Start Emissions (@ soak time) = Basic Start Emissions (@ 12 hour soak) * Soak Function

where the Soak Function is a multiplicative factor used to calculate start emissions for other soak times. The Soak Function is the grams for the soak time of interest divided by the grams for a soak time of 12 hours. At a 12 hour (720 minute) soak time, the Soak Function is equal to 1.

Mathematically, the Soak Function is defined as.

Soak Function = California Soak Function * [Ratio+(1-Ratio)*((SoakTime-10)/(720-10))]

where

California Soak Function. The values developed by the California Air Resources Board to adjust the start emissions for soak times other than 12 hours This is a function of soak time in minutes. The coefficients for catalyst vehicles, non-catalyst vehicles, and electrically heated catalyst vehicles are given in Table 4 The coefficients for catalyst-equipped vehicles are for the model year/technology groups examined in this report For example, for HC on a catalyst equipped vehicle at a soak time of 100 minutes, the value is

$0.57130 + 0.00072*100 + (-1.76E-07)*(100)^2 = 0.64154$

Ratio This parameter is calculated by dividing the EPA ratio of start emissions at 10 minutes to start emissions at 12 hours by the California Soak Function at 10 minutes. Mathematically, it is given by:

Ratio = (Start @10 minutes / Start @720 minutes) / California Soak Function @10 minutes

The numerator in the above equation (Start @10 minutes/ Start @720 minutes) was developed from FTP data using the equations in Sections 3.1.3, and dividing the Start @10 minutes by the Start @ 720 minutes. One value for each pollutant was developed that included all technologies and vehicle types. These values, used in the numerator of the equation, are HC= 0 160, CO = 0.112, and NOx = 0 204. The California Soak Function is the value obtained from the coefficients in Table 4 at a 10 minute soak point. The California Soak Function values at a 10 minute soak point for catalyst-equipped vehicles, used in the denominator of the equation, are: HC=0.1209, CO=0 1147, and NOx=0.3937. Therefore, the Ratios obtained are: HC=1 3234, CO=0.9718, and NOx=0 5182.

SoakTime: The time duration in minutes of the soak which is to be calculated (range zero minutes to 720 minutes)

The operation of the multiplicative Soak Function is illustrated in Figures 4, 5, and 6 for HC, CO, and NOx respectively   The Y-axis is the Soak Function (a unitless ratio) and the X-axis is the soak time in minutes   The California Soak Function is also shown for comparison.

For HC and NOx, the difference between the MOBILE6 soak function and the California soak function will be moderate for soak times between 30 minutes and 600 minutes   For CO, the two soak functions are very similar.

4.0   START EMISSION RESULTS

Start emissions are both a function of vehicle deterioration represented by mileage, and soak time. In previous sections the results were shown separately. In this section, examples of the results are shown with both effects combined. For example, Figures 7 through 9 show the HC, CO, and NOx start emissions as a function of soak time for three odometer levels (0, 50,000, and 100,000 miles) of 1990-93 PFI cars. For all three pollutants, the figures show low deterioration rates as mileage is increased at short soak times, and larger but constant deterioration rates at soak times after 120 minutes.

Shown below for illustration purposes is a sample calculation of start emissions. It illustrates the equations shown in Section 3.

Example: Calculate HC start emissions at a soak time of 90 minutes for a 1991 model year
             PFI-equipped car with 50,000 miles.

Start Emissions (@90min) = Basic Start Emissions (@12hr) * Soak Function

From Table 3a:
Basic Start Emissions = 2.0163 + (0.0074/1000 miles) * 50,000 miles = 2.3863g

Soak Function = California Soak Funct * [Ratio+(1-Ratio)*((SoakTime-10)/(720-10))]

From Table 4, using the coefficients for catalyst-equipped vehicles:
California Soak Funct = 0 57130 + (0 00072)*(90) + (-1.76E-07)*(90)^2 = 0 63467

Ratio = (Start@10min / Start@12hr) / California Soak Funct@10min
= 1 3234 for HC as given in Section 3 3

SoakTime = 90 minutes

Soak Function = 0 63467 * [1.3234 + (1-1 3234) * ((90-10) / (720-10))] = 0.81680

Start Emissions(@90min) = 2.3863 * 0.81680 = 1.9491g HC

Table 1
Distribution of Vehicles by Model Year and Technology*

MYR	Cars OPLP	Cars CL CARB	Cars TBI	Cars PFI	Cars ALL	MYR	Trucks OPLP	Trucks CL CARB	Trucks TBI	Trucks PFI	Trucks ALL
81	367	657	15	29	1068	81	124				124
82	71	71	74	8	224	82	45				45
83	63	57	127	62	309	83	8	3			11
84	5	30	46	35	116	84	26	22		1	49
85	24	74	56	66	220	85	33	30	13	6	82
86	7	34	60	92	193	86	14	9	23	41	87
87	1	17	76	106	200	87			6	4	10
88		15	69	113	197	88					0
89		22	38	103	163	89					0
90			160	250	410	90			144	1	145
91			91	426	517	91			141	144	285
92			57	347	404	92			92	92	184
93			29	366	395	93			90	93	183
ALL	538	977	898	2003	4416	ALL	250	64	509	382	1205

* No entry indicates no data available for that model year/technology type in the FTP dataset used for this analysis

Table 2a
Mean Start and FTP Emission Levels by Model Year for Light-Duty Cars*

| Basic start (after 12 hour soak) | | | | Start (after 10 min soak) | | | | Composite FTP | | | |
| | grams | | | | grams | | | | grams/mile | | |
MYR	HC	CO	NOx	MYR	HC	CO	NOx	MYR	HC	CO	NOx
81	4 002	46.419	1.373	81	0.610	5.115	0.041	81	0 706	9.667	0.897
82	2.445	36.378	1 237	82	0.373	4.843	-0.045	82	0 789	8 318	0 872
83	2.399	26.112	1.264	83	0.400	3 827	0 150	83	0.431	5.073	0.806
84	2.950	34 827	1.190	84	0 513	3.418	0 047	84	0 756	9.968	0 893
85	3 468	30.353	1.204	85	0.506	4.737	0.095	85	0.533	6.935	0.770
86	2.526	26.639	1 432	86	0.298	2.082	0.241	86	0 926	10 432	0 713
87	2.712	20 030	1.376	87	0 597	2 104	0 170	87	0.656	8.366	0.790
88	2.831	19.716	1 419	88	0 406	1.147	0.223	88	0 406	4.574	0 668
89	2.254	18.610	1 434	89	0.379	2.524	0.216	89	0 311	3 911	0.652
90	2 169	18.677	1.930	90	0.332	2 219	0 611	90	0.274	3.614	0.633
91	2.183	19.494	1.443	91	0 275	2.132	0.530	91	0 237	3.145	0 525
92	2.271	18 878	1 645	92	0 304	2.595	0.485	92	0.267	4 328	0.508
93	2.312	21.030	1 801	93	0.310	2 564	0.392	93	0 225	2.551	0 466

* In some isolated instances, a negative number for a start emissions estimate was obtained. This is possible when the simulated HR505 value is greater than the Bag 1 or Bag 2 value from the FTP.

Table 2b
Mean Start and FTP Emission Levels by Model Year for Light-DutyTrucks*

Basic start (after 12 hour soak)				Start (after 10 min soak)				Composite FTP			
	grams				grams				grams/mile		
MYR	HC	CO	NOx	MYR	HC	CO	NOx	MYR	HC	CO	NOx
81	7.342	107 501	1 055	81	1.212	14.211	0 385	81	1 275	18.158	1 752
82	7 909	116 584	-0.119	82	1 489	14.189	0.006	82	1.732	16.774	1.732
83	6 537	104.817	0.796	83	1 577	18.657	-0.209	83	1.361	13 226	1.436
84	5 219	95.893	0.299	84	1 098	20.057	0.004	84	0 802	10.633	1 405
85	4 766	84 621	0 457	85	0.854	7 742	0 102	85	1 281	14.465	1.388
86	3 752	41.196	0.729	86	0 607	2 148	0.128	86	0.823	8.789	1.057
87	3.352	26.635	1 266	87	0 566	1.433	0.017	87	0 401	4 610	0 605
88				88				88			
89				89				89			
90	4 705	45 331	4 683	90	0.930	7 037	0 765	90	0 800	9 510	0 885
91	3 521	41 128	2 761	91	0 878	7.129	0.519	91			
92	3 656	41 446	3 054	92	0 654	5.746	0 656	92			
93	3 644	40.557	2.736	93	0.589	4.634	- 0.676	93	0 420	5 363	0 847

* No FTP data are available for 1988 and 1989 model year light-duty trucks.

In some isolated instances, a negative number for a start emissions estimate was obtained This is possible when the simulated HR505 value is greater than the Bag 1 or Bag 2 value from the FTP.

Table 3a
Basic Start Deterioration with Mileage for Light-Duty FI Cars*

Pollutant	MY Group	Tech	Sample Size	Coefficients ZML	Coefficients Det	ZML Confidence Level Lower	ZML Confidence Level Upper	Det Confidence Level Lower	Det Confidence Level Upper	Significance ZML	Significance Det
HC	1990-93	PFI	1389	2 016	0 0074	1 885	2 148	0 0042	0 0105	0 000	0 000
HC	1990-93	TBI	337	1 835	0 0041	1 635	2 035	0 0000	0 00856	0 000	0 074
HC	1986-89	FI	657	2 145	0 0067	1 856	2 433	0 0029	0 0104	0 000	0 001
HC	1983-85	FI	392	2 476	0 0119	1 500	3 451	0 0000	0 0299	0 000	0 191
HC	1981-82	FI	126	2 435	0 0133	1 859	3 011	0 0022	0 0244	0 000	0 019

Pollutant	MY Group	Tech	Sample Size	Coefficients ZML	Coefficients Det	ZML Confidence Level Lower	ZML Confidence Level Upper	Det Confidence Level Lower	Det Confidence Level Upper	Significance ZML	Significance Det
CO	1990-93	PFI	1389	17 987	0 0572	16 292	19 682	0 0169	0 0975	0 000	0 005
CO	1990-93	TBI	337	15 649	0 0376	9 360	21 938	0 0000	0 1782	0 000	0 599
CO	1986-89	FI	657	19 443	0 0071	15 713	23 174	0 0000	0 0553	0 000	0 772
CO	1983-85	FI	392	23 378	0 0720	16 360	30 396	0 0000	0 201	0 000	0 274
CO	1981-82	FI	126	23 311	0 3489	10 345	36 275	0 0989	0 5989	0 000	0 007

Pollutant	MY Group	Tech	Sample Size	Coefficients ZML	Coefficients Det	ZML Confidence Level Lower	ZML Confidence Level Upper	Det Confidence Level Lower	Det Confidence Level Upper	Significance ZML	Significance Det
NOx	1990-93	PFI	1389	1 484	0 0020	1 381	1 588	0 0000	0 00448	0 000	0 107
NOx	1990-93	TBI	337	2 142	0 0020	1 854	2 431	0 0000	0 0085	0 000	0 541
NOx	1986-89	FI	657	1 268	0 0023	1 090	1 445	0 0000	0 0046	0 000	0 050
NOx	1983-85	FI	392	1 333	0 0028	1 119	1 545	0 0000	0 00676	0 000	0 155
NOx	1981-82	FI	126	1 679	0 0000	1 229	2 129	0 0000	0 0021	0 000	0 134

*   The basic unit of engine start emissions is defined as a start after a 12 hour soak
     ZML and Det are the regression coefficients for the zero mile level (intercept) and the deterioration rate (slope) per one thousand miles, respectively
     The confidence levels shown are the upper and lower 95% confidence intervals   Significance values less than 0 05 are considered statistically significant at
     the 95% confidence level

Table 3b
Basic Start Deterioration with Mileage for Light-Duty FI Trucks*

Pollutant	MY Group	Tech	Sample Size	Coefficients ZML	Det	ZML Confidence Level Lower	Upper	Det Confidence Level Lower	Upper	Significance ZML	Det
HC	1990-93	PFI	330	2 709	0 0000	2 482	3 308	0 0000	0 00432	0 000	0 334
HC	1990-93	TBI	467	4 112	0 0118	3 809	4 416	0 0046	0 0188	0 000	0 001
HC	1986-89	FI	74	2 312	0 0221	1 330	3 295	0 0052	0 0369	0 000	0 010
HC	1983-85	FI	20	0 834	0 0387	0 000	6 827	0 0000	0 104	0 773	0 227
HC	1981-82	FI	**	2 435	0 0133	1 859	3 011	0 0022	0 0244	0 000	0 019

Pollutant	MY Group	Tech	Sample Size	Coefficients ZML	Det	ZML Confidence Level Lower	Upper	Det Confidence Level Lower	Upper	Significance ZML	Det
CO	1990-93	PFI	330	32 237	0 0223	26 950	37 524	0 0000	0 1308	0 000	0 687
CO	1990-93	TBI	467	42 204	0 1490	37 695	46 712	0 0438	0 2536	0 000	0 006
CO	1986-89	FI	74	16 314	0 2145	2 427	30 200	0 0000	0 439	0 022	0 061
CO	1983-85	FI	20	4 421	0 2844	0 000	57 334	0 0000	0 858	0 863	0 311
CO	1981-82	FI	**	23 311	0 3489	10 345	36 275	0 0989	0 5989	0 000	0 007

Pollutant	MY Group	Tech	Sample Size	Coefficients ZML	Det	ZML Confidence Level Lower	Upper	Det Confidence Level Lower	Upper	Significance ZML	Det
NOx	1990-93	PFI	330	1 411	0 0000	1 366	1 958	0 0000	0 0004	0 000	0 067
NOx	1990-93	TBI	467	4 293	0 0033	3 836	4 750	0 0000	0 0139	0 000	0 548
NOx	1986-89	FI	74	1 245	0 0000	0 800	1 691	0 0000	0 00288	0 000	0 235
NOx	1983-85	FI	20	1 754	0 0000	0 000	3 529	0 0000	0 0060	0 052	0 166
NOx	1981-82	FI	**	1 679	0 0000	1 229	2 129	0 0000	0 0021	0 000	0 134

*   The basic unit of engine start emissions is defined as a start after a 12 hour soak   ZML and Det are the regression coefficients for the zero mile level (intercept) and the deterioration rate (slope) per one thousand miles, respectively   The confidence levels shown are the upper and lower 95% confidence intervals   Significance values less than 0 05 are considered statistically significant at the 95% confidence level

**   Due to lack of data for the 1981-82 FI truck category, the deterioration functions for the 1981-82 FI cars were used to represent this category

<p style="text-align:center">**Table 3c**
Basic Start Deterioration with Mileage for Light-Duty Open Loop and Closed Loop Carbureted Vehicles*</p>

Cars						Trucks					
Pollutant	MY Group	Tech	Number	ZML	Det	Pollutant	MY Group	Tech	Number	ZML	Det
HC	1990-93	CL Carb				HC	1990-93	CL Carb			
HC	1986-89	CL Carb	88	1 532	0 017	HC	1986-89	CL Carb	9	6 480	0 000
HC	1983-85	CL Carb	161	0 486	0 070	HC	1983-85	CL Carb	54	1 338	0 072
HC	1981-82	CL Carb	728	2 825	0 046	HC	1981-82	CL Carb	**	2 825	0 046
HC	1981+	OPLP	538	1 194	0 044	HC	1981+	OPLP	250	6 469	0 008
Pollutant	MY Group	Tech	Number	ZML	Det	Pollutant	MY Group	Tech	Number	ZML	Det
CO	1990-93	CL Carb				CO	1990-93	CL Carb			
CO	1986-89	CL Carb	88	24 300	0 089	CO	1986-89	CL Carb	9	4 111	1 415
CO	1983-85	CL Carb	161	19 495	0 496	CO	1983-85	CL Carb	54	56 604	0 830
CO	1981-82	CL Carb	728	30 953	0 483	CO	1981-82	CL Carb	**	30 953	0 483
CO	1981+	OPLP	536	19 350	0 582	CO	1981+	OPLP	250	96 418	0 231
Pollutant	MY Group	Tech	Number	ZML	Det	Pollutant	MY Group	Tech	Number	ZML	Det
NOx	1990-93	CL Carb				NOx	1990-93	CL Carb			
NOx	1986-89	CL Carb	88	1 377	0 000	NOx	1986-89	CL Carb	9	0 700	0 000
NOx	1983-85	CL Carb	161	1 189	0 000	NOx	1983-85	CL Carb	54	0 700	0 000
NOx	1981-82	CL Carb	728	1 684	0 000	NOx	1981-82	CL Carb	**	1 684	0 000
NOx	1981+	OPLP	538	0 704	0 000	NOx	1981+	OPLP	250	0 753	0 000

*   The basic unit of engine start emissions is defined as a start after a 12 hour soak   ZML and Det are the regression coefficients for the zero mile level (intercept) and the deterioration rate (slope) per one thousand miles, respectively   The confidence levels shown are the upper and lower 95% confidence intervals   Significance values less than 0 05 are considered statistically significant at the 95% confidence level

**   Due to lack of data for the 1981-82 CL Carb truck category, the deterioration functions for the 1981-82 CL Carb cars were used to represent this category

Table 4
Coefficients for Adjusting Engine Start Emissions for Soak Time
(from "Methodology for Calculating and Redefining Cold and Hot Start Emissions", CARB)

Non-Catalyst Vehicles						
	HC Curve 1	HC Curve 2	CO Curve 1	CO Curve 2	NOX Curve 1	NOX Curve 2
Constant	0 38067	0 43628	0 43803	-0 08541	1 31568	2 48061
minutes	-0 00163	0 00078	-0 00998	0 00303	0 02752	-0 00018
minutes^2	6 64E-05	0	7 01E-05	-2 11E-06	-0 00015	-2 6E-06
domain(min)	0-52	53-720	0-119	120-720	0-119	120-720

Catalyst Equipped Vehicles						
	HC Curve 1	HC Curve 2	CO Curve 1	CO Curve 2	NOx Curve 1	NOx Curve 2
Constant	0	0 57130	0	0 70641	0 11796	1 12983
minutes	0 01272	0 00072	0 01195	0 00033	0 02967	2 21E-05
minutes^2	-6 30E-05	-1 76E-07	-4 76E-05	1 00E-07	-0 00021	-3 04E-07
domain(min)	0-89	90-720	0-116	117-720	0-61	62-720

Electrically Heated Catalyst Equipped Vehicles						
	HC Curve 1	HC Curve 2	CO Curve 1	CO Curve 2	NOx Curve 1	NOx Curve 2
Constant (a)	0	0 50641	0	0 44733	1 05017	1 37178
minutes (b)	0 00561	0 00069	0 00707	0 00162	0 00362	0 00027
minutes^2 (c)	-5 09E-06	0	-1 33E-05	-1 18E-06	-5 57E-06	-1 09E-06
domain(min)	0-117	118-720	0-107	108-720	0-113	114-720

California Soak Function = a + b * minutes + c * minutes^2
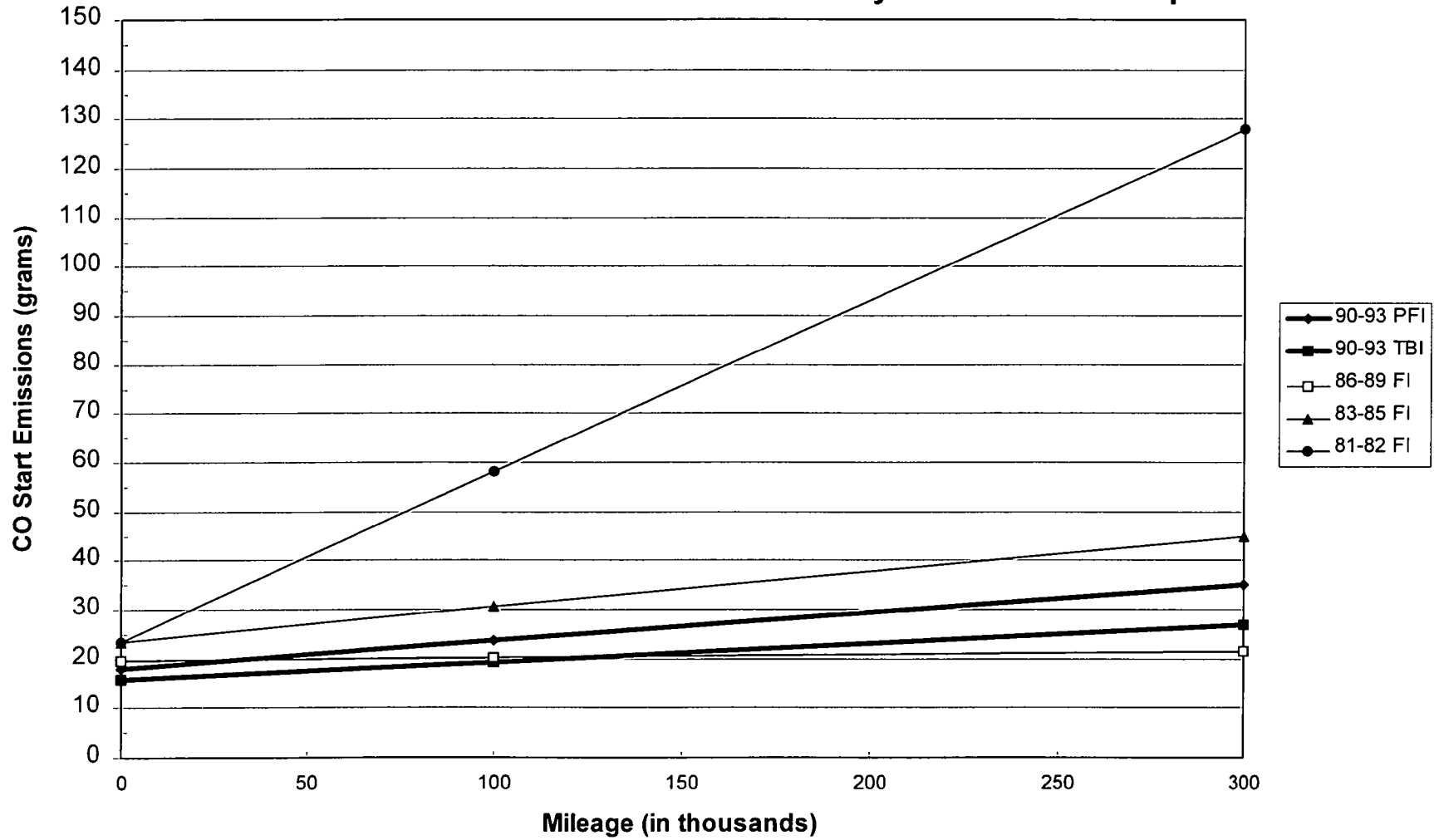(where minutes is time since last engine operation (i e , soak time))

The Soak Function is the grams per soak time i divided by the grams per overnight soak (720 minutes or 12 hours)

Figure 1
HC Basic Start Emissions for FI Cars by Model Year Group
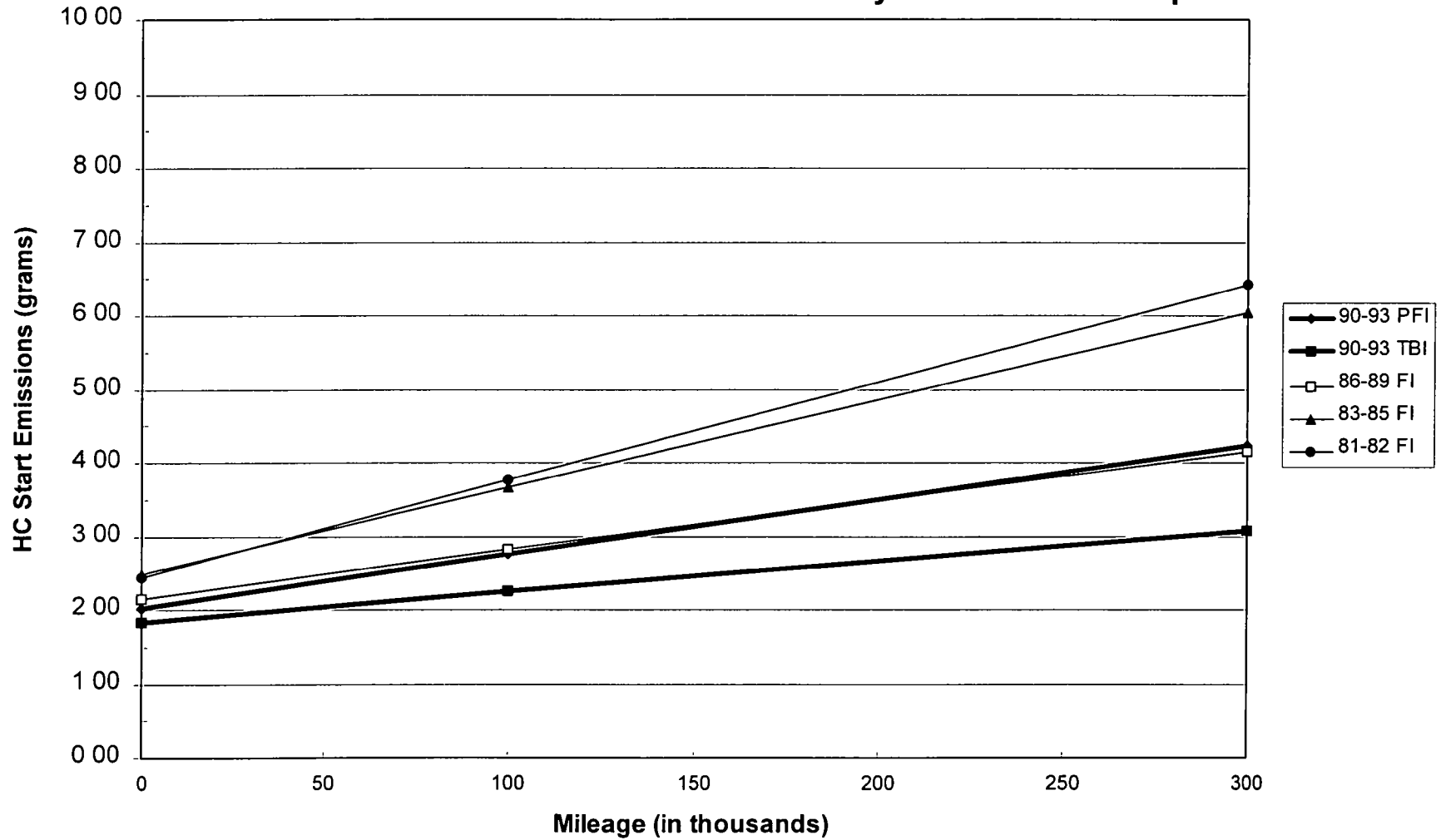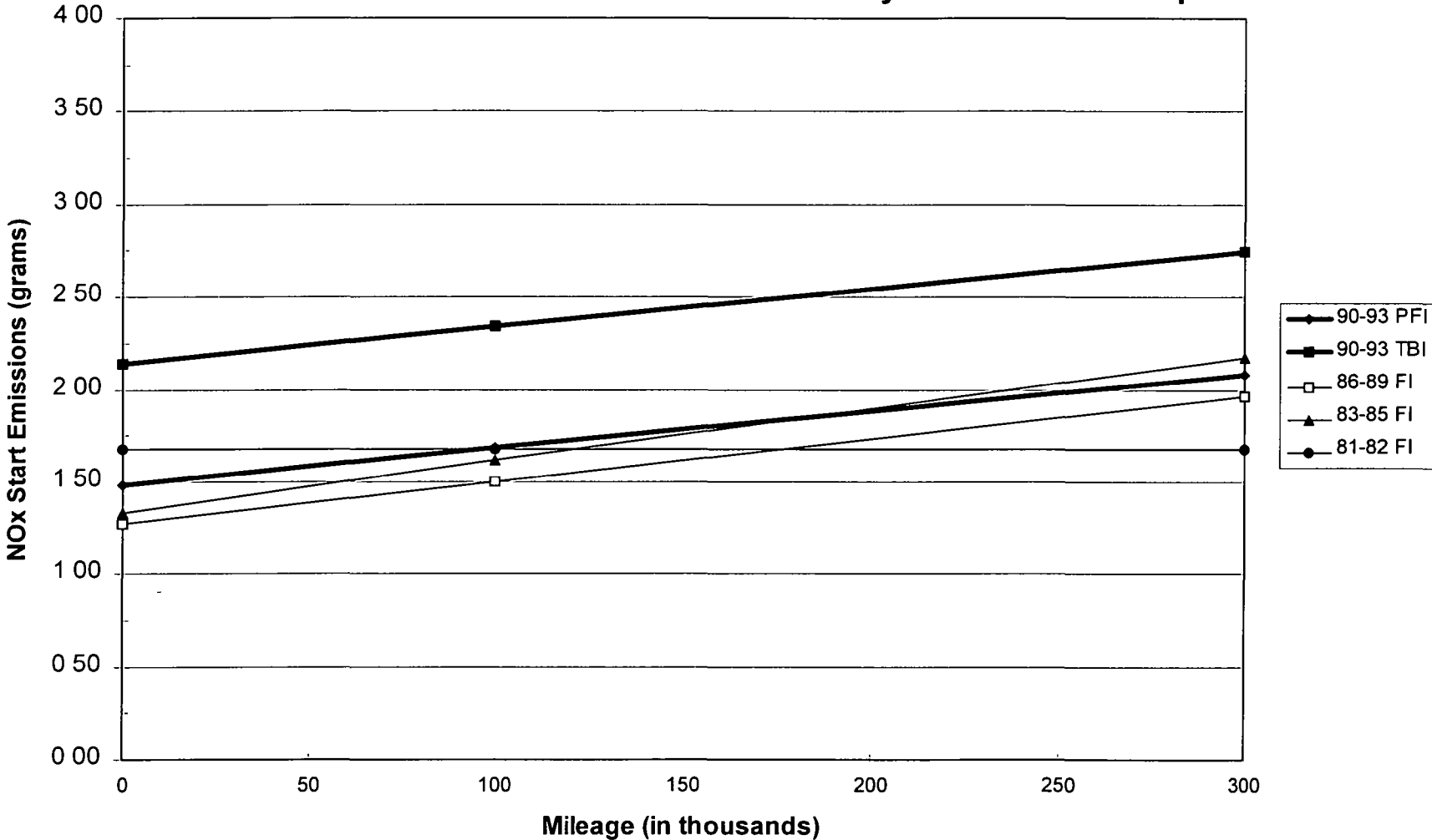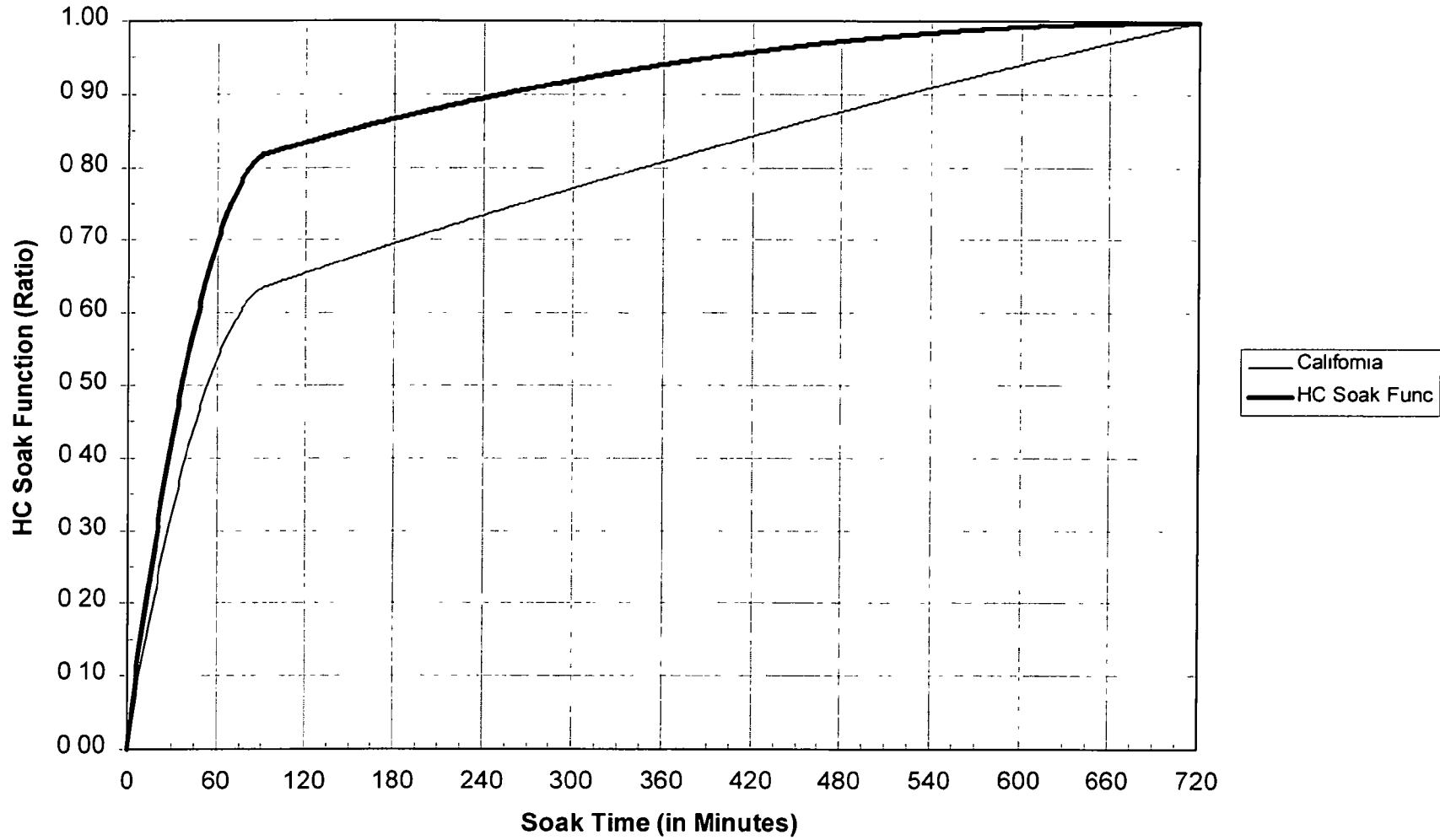
Figure 2
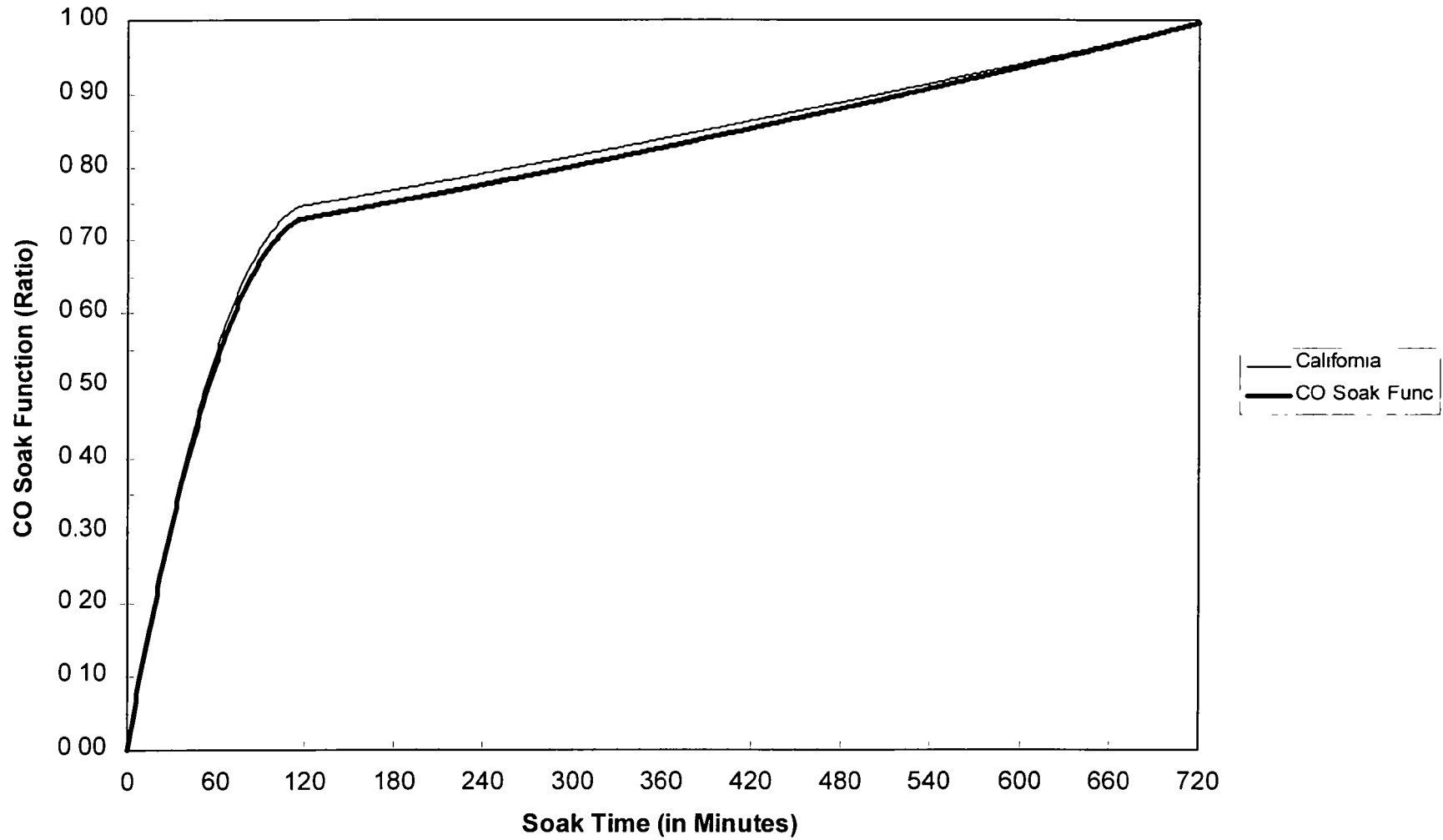**CO Basic Start Emissions for FI Cars by Model Year Group**

Figure 3
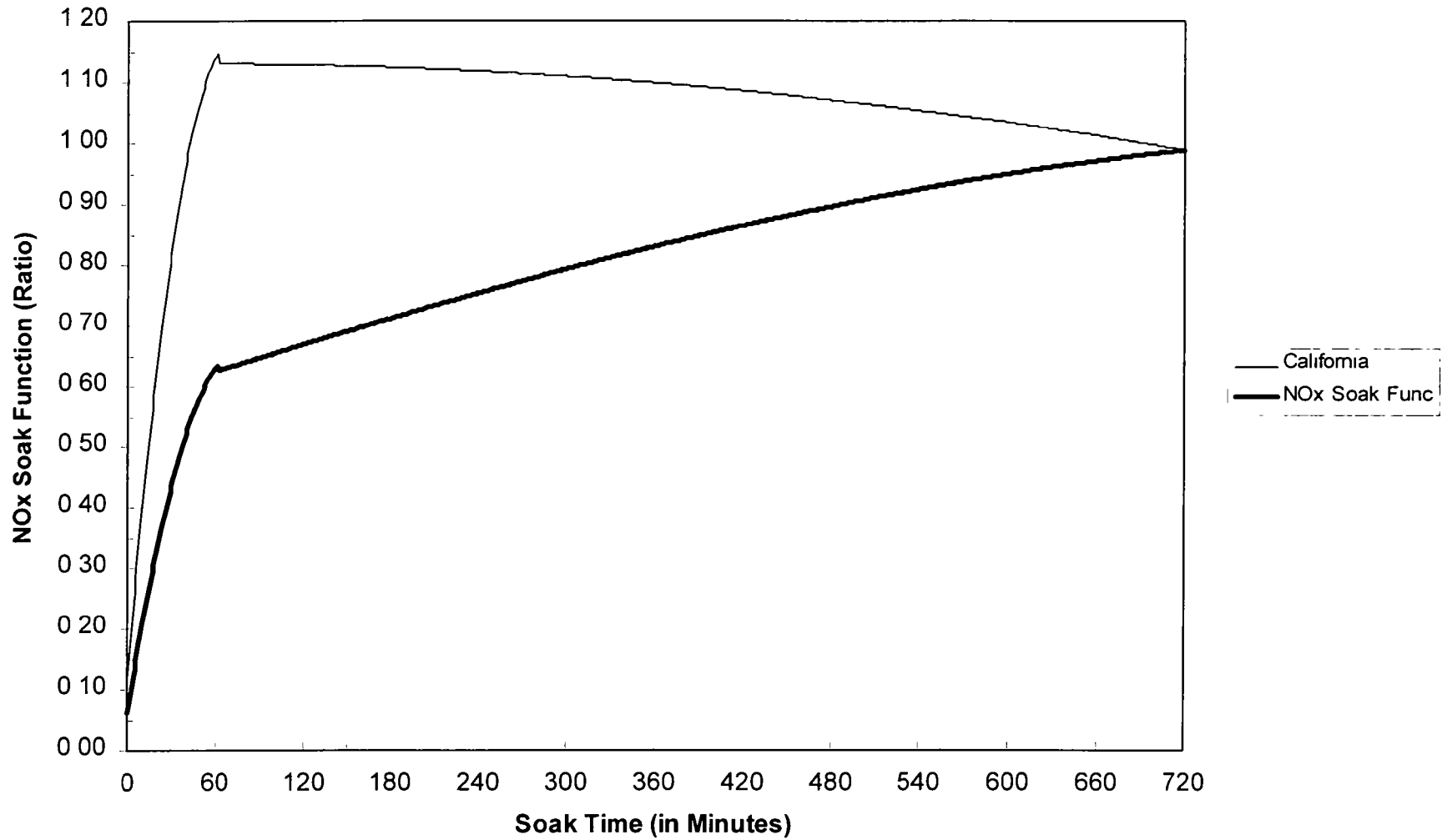**NOx Basic Start Emissions for FI Cars by Model Year Group**

Figure 4
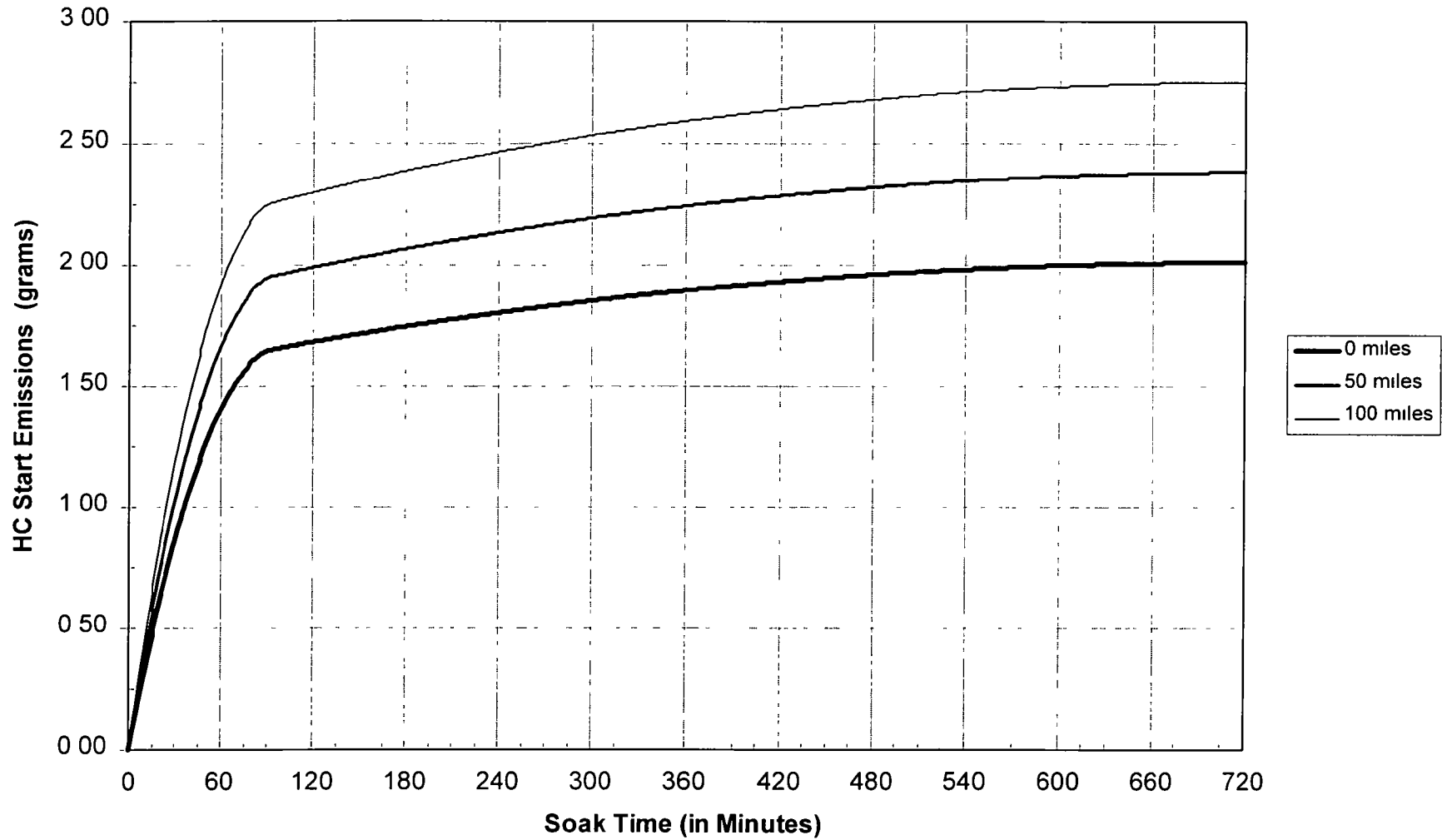**HC Soak Function vs Soak Time for 1981+ Vehicles**

Figure 5
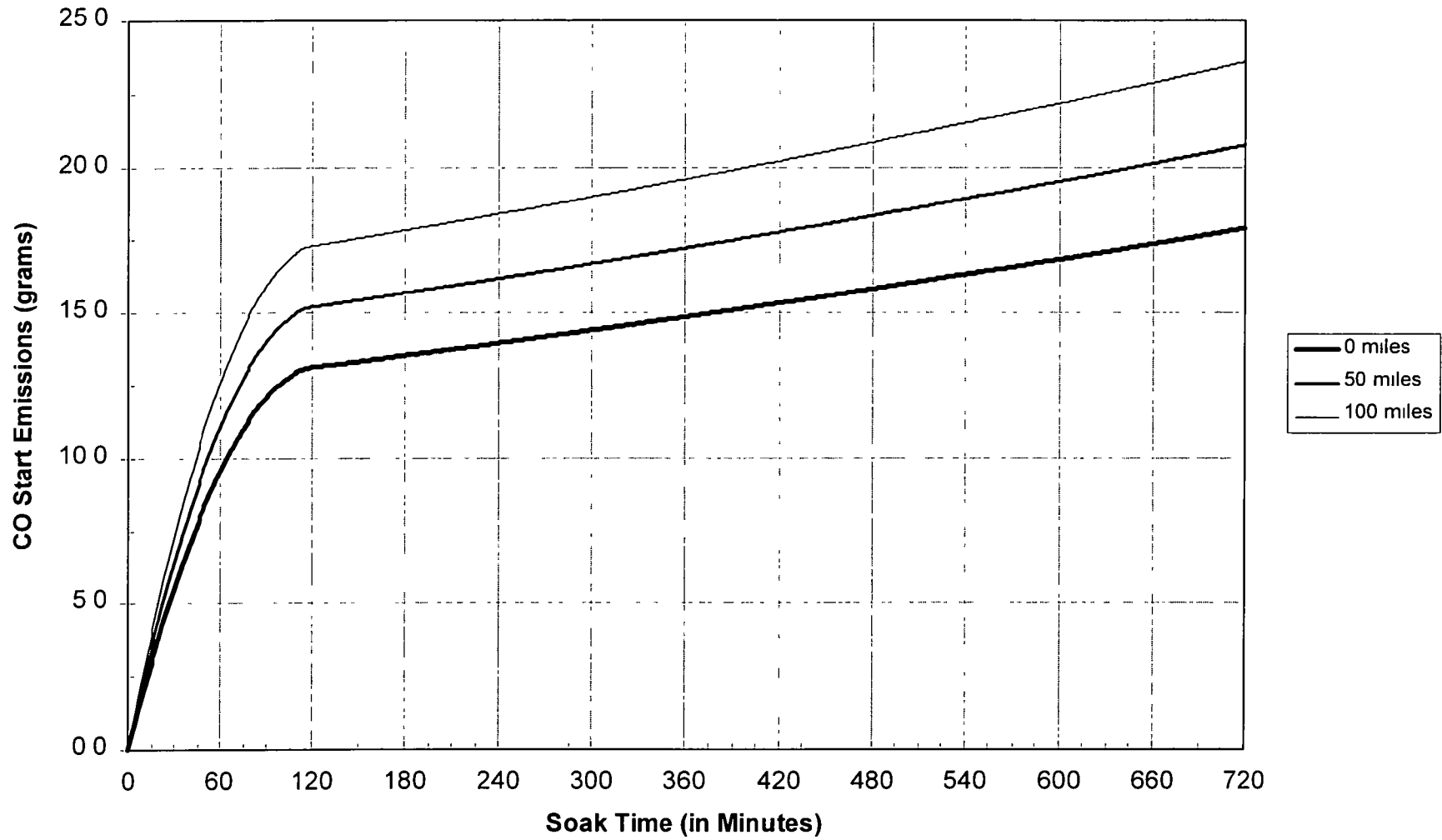**CO Soak Function vs Soak Time for 1981+ Vehicles**

Figure 6
NOx Soak Function vs Soak Time for 1981+ Vehicles

Figure 7
HC Start Emissions vs Soak Time for 1990-93 PFI Cars

Figure 8
CO Start Emissions vs Soak Time for 1990-93 PFI Cars

Figure 9
NOx Start Emissions vs Soak Time for 1990-93 PFI Cars